

## METHOD AND ARRANGEMENT FOR ARQ DATA TRANSMISSION

**Field of Invention**

5 The present invention relates to automatic repeat request (ARQ) in data communication. In particular, the present invention relates to the use of ARQ over fluctuating radio channels.

**Background of the Invention**

10 In most communication system, not at least wireless communication systems, it is of highest importance to provide a reliable protocol for delivering data units from one entity to at least another entity in the system, without loss of data and without duplication of data. Such reliable data delivery protocols typically relies on the principle that the receiver of the data responds to the sender of the data with acknowledgements upon reception of the data and/or negative acknowledgements if the data units were lost. The sender will subsequently to the acknowledgement send the next data unit, or if a negative acknowledgement, retransmit the  
15 lost data unit.

Automatic repeat request (ARQ) is one of the most common retransmission techniques in communication networks, and ensures reliable user data transfer and data sequence integrity. The data is, prior to the transmission, divided into smaller packets, protocol data units (PDU). A reliable transfer is enabled by encoding packets with an error detecting code, such that the  
20 receiver can detect erroneous or lost packets and thereby order retransmission. The data sequence integrity is normally accomplished by sequential numbering of packets and applying certain transmission rules.

In the most simple form of ARQ, commonly referred to as Stop-and-Wait ARQ, the sender of data stores each sent data packet and waits for an acknowledgement from the receiver of a  
25 correctly received data packet, by the way of a acknowledgement message (ACK). When the ACK is received, the sender discard the stored packet and sends the next packet. An example of a prior art Stop-and-Wait ARQ scheme is schematically depicted in the message sequence chart of FIG. 1a. The process is typically supplemented with timers and the use of negative acknowledgement messages (NACK), which is illustrated in FIG. 1b. The sending entity uses  
30 a timer, which is started on the transmission of a data packet, and if no ACK has been

received before the timer expires the data packet is retransmitted. If the receiver detects errors in the packet it can send a NACK to sender. Upon receiving the NACK the sender retransmit the data packet without waiting for the timer to expire. If the ACK or NACK message is lost, the timer will eventually expire and the sender will retransmit the data packet. From the

5 simple Stop-and-Wait, more elaborated schemes of the conventional ARQ has been developed, for example Go-Back-N and Selective Reject (or Selective Repeat), which provides a higher throughput. Taught in WO 02/09342 by Dahlman et al. is a ARQ scheme that adds flexibility to the traditional ARQ scheme by introducing ARQ parameters that are set and/or negotiated to give a desired trade-off as regard to communication resources.

10 In another line of development of the ARQ, the redundancy in the coding is exploited in various ways to enhance communication performance (generally measure as throughput). These schemes are referred to as Hybrid ARQ schemes. Due to the combination of coding and ARQ, the hybrid ARQ schemes can give a certain adaptation to changes in the radio environment, e.g. to fading. How to best combine ARQ and coding schemes to cope with  
15 fading channels is not trivial. Several approaches and schemes have been suggested and used.

In Hybrid 1 ARQ Forward Error Correction (FEC) is combined with ARQ. In Hybrid 2 ARQ a PDU is sent more or less uncoded, but accompanied with a Cyclic Redundancy Check (CRC) for checking presence of bit errors after decoding. If CRC fails, i.e. errors are detected, then the PDU is requested for retransmission, and a codeword which is generated based on the  
20 data transmitted with the first PDU is sent. The codeword may have such character that the original dataword can be determined solely by decoding the codeword or it may be combined with the previously received PDUs content, and thereby improving the chance of decoding the data word without errors. The coding may for instance employ so-called half rate invertable codes. A version of Hybrid 2 ARQ is used in UMTS. Another Hybrid ARQ method is to  
25 combine a PDU that is transmitted multiple times by maximum ratio combining (or similar such as interference Rejection Combining). Disclosed in US patent nr. 6,308,294 by Ghosh et al. is a method of combining so called turbo codes with Hybrid ARQ, which allows retransmission of different sizes, and increased adaptability to fading channels.

As exemplified above advantages have been made in providing ARQ schemes that increases  
30 throughput and/or offer flexibility with regards to channel quality. However, the prior art methods suffers from drawbacks, mainly:

Conventional non-Hybrid ARQ schemes, but to some extent also Hybrid ARQ schemes, are inefficient when the channel quality changes unpredictable. Such changes may be caused by that the radio channel fluctuates due to fading, or that interference fluctuates unpredictable due to fading or/and due to unpredictable traffic fluctuations.

- 5 Further may the channel fluctuation cause inaccuracies in channel measurements and/or that outdated channel measurements are used for link mode selection. This may cause packets to be sent with a rate that is not decodable if the interference and noise is greater than permitted for the selected rate. Alternatively, a margin may be introduced and a reduced rate used, but this is done with the “cost” of not efficiently use the channels that can bear a higher rate.
- 10 In addition, complex ARQ schemes, especially the more advanced Hybrid ARQ schemes, are complicated to implement and require a high degree of optimization to fully take advantage of the increased throughput that is theoretically possible. Often the lack of system optimization, which has become very complex, makes the wireless systems deliver less throughput than the Hybrid ARQ schemes are capable off.

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### **Summary of the Invention**

Obviously an improved ARQ method, that quickly and automatically adapts to channel quality changes is needed.

- 20 The object of the present invention is to provide a method, system and programs that overcomes the drawbacks of the prior art techniques. This is achieved by the method as defined in claim 1, the system as defined in claim 11, the device as defined in claim 17 and the program product as defined in claim 9.

- 25 In the method according to the present invention a sender and a receiver are engaged in wireless communication with each other, wherein the sender is provided with an incoming data stream of a plurality of protocol data units (PDUs). The sender transmit a plurality of PDUs which are at least partially overlapping and at least two different transmission power levels are used for the transmission of at least two different PDUs.

One embodiment of the method according to the present invention comprises the steps of:

- a)-*grouping* of PDUs, wherein a number of PDUs from the to the sender incoming data stream are group into a set of PDUs, and each PDUs are given a sequence number ( $n$ );
- b)-*assigning* Transmit Power and Code rate to PDUs. wherein each PDU is assigned a  
5 transmit power level value ( $P_k$ ) and a code rate value ( $C_k$ );
- c)-*storing* PDUs, wherein the PDUs are stored in a memory along with their sequence number ( $n$ ), and the assigned power level value, ( $P_k$ ), and code rate value ( $C_k$ );
- d)-*transmitting* PDUs, wherein the PDUs of the set of PDUs are simultaneously transmitted from the sender with their respective power level value ( $P_k$ ) and code rate value ( $C_k$ ),
- 10 e)-*receiving* PDUs, wherein the transmitted PDUs are received by the receiver, decoded and checked for errors (CRC), and PDUs not considered decodeable are recognised as not correctly received;
- f)-*feedbacking* (ARQ), wherein the receiver transmit to the sender an ARQ feedback in form of a ACK or NACK message, wherein the message comprises information on the PDUs
- 15 which were correctly received or the PDUs which were not correctly received, respectively;
- g)-*discarding* correctly received PDUs from memory, wherein the sender discard from the memory the temporally stored PDUs, which was correctly received, and forming a new set of PDUs comprising the PDUs which were not correctly received and PDUs from the incoming data stream;
- 20 h)-*repeating* steps b) to g), whereby retransmitting the not correctly received PDUs at higher power levels than the previous transmission.

The system according to the present invention comprises of a sender and at least one receiver adapted to be engaged in mutual wireless data communication, the system using automatic repeat request (ARQ) in the data communication, wherein the sender is provided with an  
25 incoming data stream of a plurality of protocol data units (PDUs). The sender transmit a plurality of PDUs which are at least partially overlapping, and at least two different transmission power levels are used for the transmission of at least two different PDUs.

Thanks to the inventive method and system a radio channel adaptation that is opportunistic with respect to channel variations is provided. A higher number of PDUs will be transmitted  
30 when the channel so permits, and a lesser number if the instantaneous channel quality is low. Whereby, the method ensures that at each transmission instance there will be a very high

probability of that at least a part of the transmitted PDUs are correctly received i.e. some information will almost always be transferred. This is in contrast to prior art ARQ schemes (both conventional and Hybrid schemes), wherein, in some cases, no information at all will be transferred.

- 5 One advantage of the present invention is that thanks to the ability of fast channel adaptation in combination with a high probability of some PDUs will be correctly received in every attempt, a less precise channel feedback is needed. In other words, the invention increases robustness against unpredictable channel fluctuations. In addition this adaptation is performed with relatively low complexity, ensuring a fast and reliable implementation.
- 10 A further advantage afforded by the method according to the present invention is that it offers backward compatibility to legacy terminals in most communication systems. The idea is that base stations and new terminals implements the novel ARQ- scheme, whereas legacy terminals merely see the coarsest level and decode the same but with somewhat degrade performance due to the interference caused by underlying (with respect to power level) PDUs.
- 15 Embodiments of the invention are defined in the dependent claims. Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings and claims.



**Brief Description of the Drawings**

The invention will now be described in detail with reference to the drawing figures, wherein

Fig. 1 a) and b) are message sequence chart of conventional ARQ schemes;

Fig. 2 is a flowchart over the method according to the present invention;

5 Fig. 3 is a message sequence chart of the method according to the present invention;

Fig. 4 is a message sequence chart illustrating an exemplary implementation of the method according to the present invention; and

Fig. 5 is a schematic view of an exemplary implementation architecture suitable for the present invention; and

10 Fig. 6 illustrates the method according to the invention used on a channel that exhibit time varying fading.

**Detailed Description of the invention**

In a typical scenario for using ARQ, two or more entities are engaged in wireless  
15 communication with each other. The communication is commonly referred to as being over a radio channel, which for example is a logical channel in a wireless communication system such as UMTS. The entities are capable of both transmitting and receiving radio signals. For the clarity of the description, the entity that is to transmit a payload of data is referred to as the sender, and the entity that is to receive the data is referred to as the receiver, even though in  
20 the ARQ processes both entities receives and transmit signals over the channel. As discussed in the background section, fading fluctuation and interference fluctuations caused by traffic variations, may cause the channel quality to change unpredictable. Illustrated in FIG. 2. is the “uncertainty” of the carrier to interference ratio (CIR) as a probability density function in a typical traffic and fading scenario. As can be understood from the figure, an average channel  
25 quality may be defined, but the channel quality will quite frequently deviate substantially from that average, and a transmission at one time instance can experience both better and worse channel quality than the average quality. In the same manner, if an instant measure of the channel quality is used as a reference, the probability of that measure not being  
30 representative of the channel quality is fairly high. Measures of the channel quality are performed in all wireless systems, for example by measuring BER, and used as a basis for

determining transmit power, link adaptation etc. As described above, the known ARQ schemes become inefficient when the channel quality changes unpredictable.

The method according to the present invention provides an ARQ scheme that is well suited to a situation of changing channel quality. According to the method the sender transmits a set of multiple PDUs at essentially the same time multiplexed on different power levels and preferably with fairly low (code) rate for each PDU. Each PDU 205 in the set 210 is given a sequence number  $n$  and is assigned an individual code rate  $C_n$  and an individual power level  $P_n$ . The code rate and power levels are chosen so that between one and all transmitted PDUs are decodable by the receiver in presence of noise and interference. The number of decodable PDUs depends on the noise level, indicated at 215, and which powers the PDUs are received with. The PDU with lowest sequence number is preferably assigned the highest power, and the following sequence numbers are assigned with subsequent lower transmit power. If a PDU in the set that has failed the decoding process, a retransmission is ordered through a ACK or NACK procedure. The lost PDU is then given the lowest sequence number for the transmission, hence uses the highest power. Alternatively, or in combination, the PDUs are given different coding i.e. different data rate.

Various known modulation/multiplexing methods may be used for the simultaneous transmission, e.g. Multi Resolution Modulation (MRM), Direct Sequence- Code Division Multiple Access DS-CDMA or "Turbo-coded" CDMA.

For decoding can also various known methods be used, such as Multi User Detection (MUD) schemes including Successive Interference Cancellation (SIC), Parallel Interference Cancellation (PIC), Maximum Likelihood Detection, etc.

An embodiment, representing the basis for an implementation, of the ARQ method according to the present invention will be described with reference to the message sequence charts of FIG. 2 and 3 and the flowchart of FIG. 4. The method comprise the steps of:

405: Grouping of PDUs.

A number of PDUs from the to the sender incoming data stream, are group into a set of PDUs. The PDUs are given respective sequence numbers according to  $n, n+1, n+2, \dots, N+n-1$ . The number,  $N$ , of PDUs in a set is typically given by the capability of

multiple transmissions and/or decoding of the used modulation/multiplexing method and decoding method, respectively.  $N$  is typically a predetermined value, but can also be a parameter.

410: Assign Transmit Power and Code rate to PDUs.

- 5 Each PDU is assigned a transmit power level value  $P_k$  and a code rate value  $C_k$ , wherein  $k=1, 2, \dots, N$ . Preferably the PDU with the lowest sequence number ( $n$ ) is assigned the highest power level value  $P_1$ , and the subsequent PDUs are assigned to decreasing power levels,  $P_2$ ,  $P_3$ ,  $P_4$ , etc. The power level values preferably ranges from a value above the estimated needed transmission power (from corresponding measure of the channel quality), to ensure a high
- 10 probability for that PDU to be correctly received, to values below the estimated needed transmission power. The PDUs transmitted with the lower transmission powers will have less probability of being correctly received, but with regards to the probability density function of FIG. 2, it is understood that also a PDU transmitted with considerably lower power than the estimated needed transmission power may be successfully received.

15 415: Storing PDUs.

The PDUs are stored in a memory along with their sequence number,  $n$ , and the assigned power level value,  $P_k$ , and code rate value  $C_k$ .

420: Transmitting PDUs.

- 20 The PDUs ( $n$  to  $N-1$ ) of the set of PDUs are simultaneously transmitted from the sender with their respective power level value,  $P_k$ , and code rate value  $C_k$ .

425: Receiving PDUs.

- The transmitted PDUs are received by the receiver, decoded and checked for errors (CRC). Typically are a subset of the PDUs correctly received. The rest of the PDUs are probably below the noise floor at the moment of transmission, as indicated in FIG. 4a, and regarded as
- 25 lost. Generally the subset of correctly received PDUs comprises subsequent PDUs  $n, n+1, n+2, \dots, R$ , wherein  $R$  represents the highest sequence number, corresponding to the lowest transmit power,  $P_R$ , that gave a correctly received PDU.

430: ARQ feedback.

The receiver transmits an ARQ feedback to the sender in form of an ACK or NACK message.



In case of an ACK, the message comprises the sequence numbers of the PDUs in the subset of correctly received PDUs (typically  $n, n+1, n+2, \dots, R$ ). In case of a NACK, the message comprises the sequence numbers of the transmitted PDUs that were not correctly received, i.e. not in subset (typically  $R+1, R+2, \dots, N+n-1$ ). Alternatively the ACK or NACK messages  
 5 comprises a representation of  $R$ , indicating that sequence numbers up to  $R$  were correctly received, or indicating that sequence numbers after  $R$  were incorrectly received, respectively.

435: Discarding correctly received PDUs from memory.

Upon reception of the ACK or NACK message, the sender discard from the memory the temporally stored PDUs, which was correctly received, i.e. the subset  $n, n+1, n+2, \dots, R$ . A  
 10 new set is regrouped wherein the PDUs which were not correctly received ( $R+1, R+2, \dots, N+n-1$ ) are given the lowest sequence numbers, and hence will be given the highest transmission power level values. The set is then "filled up" with new PDUs from the incoming data stream,  $R+1, R+2, \dots, N+n-1$  units.

440: Repeat step 410 to 435.

15 The assigning, transmission and ARQ process is repeated for all PDUs of the incoming data stream.

Depending on the result of a transmission of a set of PDUs, the total power level, the maximum power level  $P_1$ , the intervals between power levels and the code rate values, can be adjusted between the transmissions of sets.

20 Illustrated in the message sequence chart of FIG. 3 is an example of the method according to the present invention with four possible simultaneous transmissions ( $N=4$ ), i.e. four power levels  $P_1, P_2, P_3$ , and  $P_4$ . The first set will comprise of PDU<sub>1</sub>, PDU<sub>2</sub>, PDU<sub>3</sub>, and PDU<sub>4</sub> (step 405), with assigned power levels  $P_1, P_2, P_3$ , and  $P_4$ , and code rates  $C_1, C_2, C_3$ , and  $C_4$  (step 410). The transmission (step 420) results in that only PDU<sub>1</sub>, PDU<sub>2</sub>, are correctly received  
 25 (step 425). The receiver send a NACK message informing the sender that PDU<sub>3</sub>, and PDU<sub>4</sub> were lost (step 430). At the sender a new PDU set is formed (step 435) with PDU<sub>3</sub>, PDU<sub>4</sub>, PDU<sub>5</sub>, and PDU<sub>6</sub>, which will be transmitted with power levels  $P_1, P_2, P_3$ , and  $P_4$ , respectively.

The relation between power levels, code and interference plus noise level relations, depends on modulation and coding scheme as well as the decoder structure. As an illustrative example,

one may assume that Shannon limit approaching codes and a successive interference cancellation based receiver are used. Further, for simplicity one may assume that each PDU can be considered as a white noise sequence without any structure. One may further assume that one has decided which rates each level should be used, here denoted  $C_k$ , where  $k$  is in the range 1 to  $K$ . Moreover, the PDUs will be decodable at certain SNR levels, or equivalently at certain interference level thresholds. Now, assume that those threshold levels are denoted  $I_k$ . Then the power levels  $P_k$  for each level can be determined as:

$$C_N = \lg_2 \left( 1 + \frac{P_N}{I_N} \right), C_{N-1} = \lg_2 \left( 1 + \frac{P_{N-1}}{I_{N-1} + P_N} \right), C_k = \lg_2 \left( 1 + \frac{P_k}{I_k + \sum_{j=k+1}^N P_j} \right).$$

A possible exemplary implementation architecture wherein Multi Resolution Modulation is used to multiplex the different ARQ PDUs in different hierarchies, is shown in FIG. 5. An unmodulated data stream 505 is fed to a transmitter unit 510. In an ARQ TX block 515 the PDUs are group into a set and assigned individual transmit power and/or code rate (steps 405 and 410) followed by a coding and modulation block 520 in which the PDUs are coded with for example FEC+CRC and modulated. The ARQ TX block 515 further comprises a storing module 517, wherein the PDUs are stored temporarily (step 415) while awaiting the ARQ feedback (step 430), and a discarding module 518 (step 435). The signals are mixed and combined by mixers 525 and a combiner 530 and transmitted as modulated data 535 over the air interface (step 420).

On the receiving side, the receiver 540 receives the modulated data (step 425). In a decoding block 545 the individual PDUs are restored and by the CRC functionality it determines which PDUs that are not correctly received. The PDUs are fed to the ARQ RX block 550 that order the ARQ TX 515 to retransmit the incorrect PDUs (step 430) as indicated with ARQ feedback 552. Outputed from the receiver 540 is the demodulated data 555, which should correspond to the unmodulated data 505.

FIG. 6 illustrated the ARQ method according to the invention under operation in the time domain for a fading channel, where the coherence time is larger than the time slot durations

used to send the PDUs. As shown in the figure, the number of PDUs that are correctly received will vary in time due to the variations of the radio channel and interference.

The present invention is exemplified primarily in the light of a flat channel. However, it may also be used over channel that varies e.g. OFDM with frequency selectivity.

5 In addition, PDUs that are decoded at one time instance can be cancelled from the baseband signals. This residual baseband signal can then be used in combination of new received signals, e.g. by maximum ratio combining.

The proposed hierarchical ARQ scheme may also be used in combination with other Hybrid-ARQ methods, by using different FEC codes for the same PDU depending if it is the first,  
10 second, thirds (and so on) time the PDU is sent.

The present invention may also be used in conjunction of advanced antenna concepts including, but not limited to beamforming and MIMO based communication, for example.

The method according to the invention can be described as giving a radio channel adaptation that is opportunistic with respect to channel variations- a higher number of PDUs will be  
15 transmitted when the channel so permits, and a lesser number if the instantaneous channel quality is low. Whereby, the method ensures that at each transmission instance there will be a very high probability of that at least a part of the transmitted PDUs are correctly received i.e. some information will almost always be transferred. This is in contrast to prior art ARQ schemes (both conventional and Hybrid schemes), wherein, in some cases, no information at  
20 all will be transferred.

Alternatively, or in combination with the above, the ability of fast channel adaptation provided by the present invention, may be utilized in that less precise channel feedback is needed, since the invention increases robustness against unpredictable channel fluctuations. In addition this adaptation is performed with relatively low complexity, ensuring a fast and  
25 reliable implementation.

The method according to the present invention offers backward compatibility to legacy terminals in most communication systems. This can be achieved in that base stations and new terminals implements the novel ARQ- scheme, whereas legacy terminals merely see the

coarsest power level and decode the same, possibly with somewhat degrade performance due to the interference caused by underlying (with respect to power level) PDUs.

5 The method according to the present invention is preferably implemented by means of program products or program module products comprising the software code means for performing the steps of the method. The program products are preferably executed on a plurality of entities within a network. The program is distributed and loaded from a computer usable medium, such as a floppy disc, a CD, or transmitted over the air, or downloaded from Internet, for example.

10 While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, on the contrary, is intended to cover various modifications and equivalent arrangements within the appended claims.